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Monte Carlo Simulation for Tire and Oil Inventory Optimization at PT X

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ABSTRACT

PT X is a distributor of genuine and aftermarket spare parts such as batteries, tires, oil, and other components for various types of cars and trucks. Currently, PT X places orders only when the product inventory is very low or depleted without considering the optimal stock quantity. As a result, PT X often experiences stockouts when there is consumer demand, especially for tires and oil products, whose stock levels frequently fall below the company's standard inventory levels. This study aims to address the issue of product availability for tires and oil by implementing an effective inventory control method. The methods used in this study include FSN analysis to classify inventory priorities based on their movement rate, Monte Carlo simulation to predict product sales in upcoming periods, and the determination of safety stock and reorder point to prevent future stockouts. The data processed in this study are the purchase and sales data of 25 tire and oil products during the period from March to August 2023, during which 25 products experienced stockouts. The results of the study show that by using FSN analysis, Monte Carlo simulation, and the determination of safety stock and reorder point, PT X can prioritize tire and oil products with high inventory turnover rates for special attention, optimize the inventory of tire and oil products by predicting future sales volumes, and reduce the risk of stockouts by determining safety stock levels and reorder points.

Keywords: *Inventory Priority, Inventory Optimization, Stock Out, Monte Carlo Simulation.*

Introduction

Inventory control is a managerial function to manage every need for goods, both in the form of raw materials, goods in process, and finished goods so that they are always available in stable and fluctuating conditions [1]. Inventory control has an important role in the supply chain because it involves significant investment [2]. If the supply is too much, it can result in the occurrence of overstock which can increase storage costs and the risk of product damage [3]. On the other hand, if the supply is too small, it can result in a shortage of stock (stockout) which leads to losses due to unmet consumer needs [4]. PT X is one of the distributors spare part genuine and aftermarket which sells products such as tires, oil, batteries, wheels, bearings, and other vehicle components. PT X has an important role to ensure that spare part available to meet consumer needs. Therefore, effective inventory management is very important to ensure product availability so that the product distribution process can run smoothly until it reaches consumers.

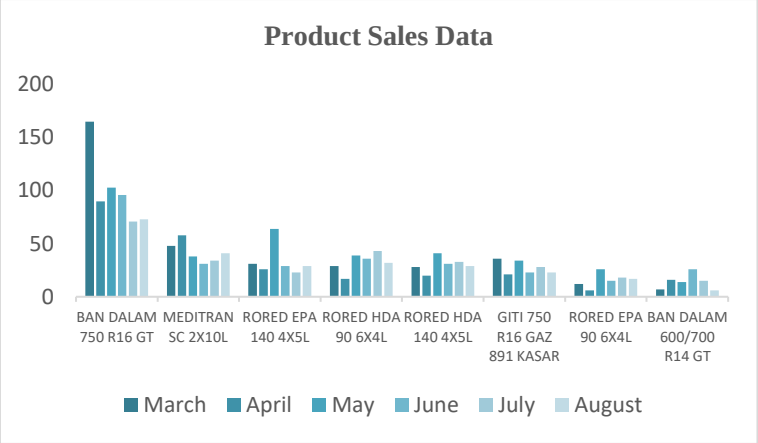

Figure 1. Tire and oil product sales chart

Based on **Figure 1.** above, the tire and oil sales chart show an increase and decrease in the number of product sales throughout March – August 2023. The non-constant sales of products every month resulted in PT X experiencing problems in terms of determining optimal inventory. Currently, PT X does not have a good inventory planning system and does not have a basis in terms of determining the number of quantities ordered and when to place an order. PT X often pays little attention to the state of tire and oil supplies, where the policy carried out by PT X is to order when the product supply is very thin or even exhausted. In this case, PT X often experiences product sales losses due to a shortage of product stock (stockout) when there is demand by consumers, resulting in losses for both the company and consumers.

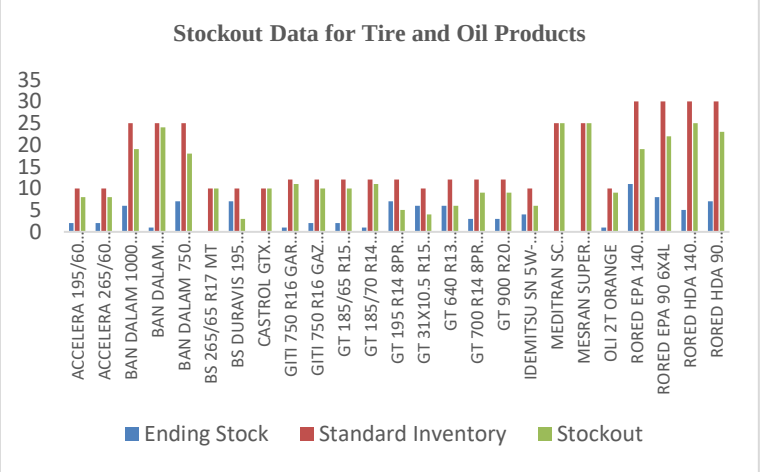

Figure 2. Tire and oil product stockout data

Based on **Figure 2.** there are 25 products that are experiencing a shortage of stock due to the lack of precision in PT X's policy in terms of determining optimal inventory. PT X has a standard inventory for each product that is used as a reference to ensure that tire and oil products are available in sufficient quantities to meet consumer demand. However, the reality is that the number of stocks is below the standard inventory value set, so PT X is unable to meet consumer needs. To overcome this problem, PT X needs an inventory control system that can ensure the availability of products. The research method that will be applied to this study is FSN (Fast, Slow, Non-Moving) analysis to group inventory based on the rate of product movement, Monte Carlo simulation to predict future sales. Then, the prediction results from the Monte Carlo simulation will be used to determine the value of the safety stock and the reorder point, so that PT X can overcome the possibility of fluctuations in product demand and ensure that the reorder point is correct. By paying attention to the value of safety stock and the reorder points produced, it is hoped that PT X will be able to plan and control inventory against consumer demand, so that the inventory of tire and oil products can be optimal and no longer experience stockouts or excess stock.

The FSN analysis method is a technique to group goods based on the level of consumption in goods by paying attention to the frequency of their use [5]. This method classifies goods into 3 categories, namely fast moving, slow moving, and non-moving. The consumption rate of goods can be determined based on the value of Turn over ratio which refers to the inventory turnover for one year [6]. Simulation

is a modeling method that represents interactions in a system to produce system behavior that is similar to the actual state [7]. Simulations are carried out to support the decision-making process in solving a problem [8]. Monte Carlo simulation is a form of probabilistic simulation with a random process (random) which includes the probability distribution of data variables based on historical data [9]. This method generates random numbers (random number) used in the simulation model [10]. Monte Carlo simulation is included in the sampling because the input is generated randomly (generate random) from probability distributions that can be used to predict demand, so that it can anticipate soaring demand [11]. Safety stock or safety supplies are the amount of inventory maintained to protect against the risk of shortage of goods (out of stock) as a result of the demand level exceeding the existing inventory level [12]. The purpose of holding the safety stock is to assist operational planning in the face of demand uncertainty by consumers [13]. Factors that affect the size of safety stock include consumer uncertainty, standard deviation, variation in waiting time (lead time) delivery, and service level or the degree of likelihood that the company can meet consumer needs [14]. Reorder point is the value or point at which the re-inventory order is placed [15], which is used to determine the reorder point, so that the stock order arrives on time when the inventory reaches the safety inventory point [16]. Factors influencing the calculation reorder point, i.e. the number of stock requests and lead time when inventory begins to be ordered until the inventory arrives in the company's hands [17].

Research Methods

The method used in this study is using the FSN analysis method, Monte Carlo simulation, safety stock and reorder point to optimize the inventory of tire and oil products. The data used in this study is data on the purchase and sale of 25 tire and oil products throughout the period of March – August 2023.

The stages of this study are as follows:

1. Collect data in the form of primary and secondary data
2. Classified 25 tire and oil products using FSN analysis. The stages are, determining the initial inventory, final inventory, calculating the average value of inventory, calculating the partial Turn Over Ratio (TORp), calculating the average product storage time, calculating the product movement rate or Turn Over Ratio (TOR), and then classifying based on the value of the Turn Over Ratio (TOR).
3. Predict sales of fast-moving classified products with Monte Carlo simulations. The stages are, determining probability distributions, cumulative probability distributions, random number intervals, generating random numbers, and creating Monte Carlo simulation models.
4. After the simulation is generated, an accuracy test process is carried out to measure the extent to which the model is made in accordance with the actual data by calculating the MAD, MSE, and MAPE values.
5. Determine policy proposals in the form of safety stock and reorder points to overcome the risk of stock shortages in the future.

Results and Discussion

This study uses the FSN analysis method and Monte Carlo simulation to classify oil tire products based on their displacement rate and to predict the sales of oil tire products in the next 6 months (September 2023 – February 2023) in order to optimize the inventory of tire and oil products. In addition, safety stock and reorder points will be determined to overcome the risk of stock shortages in the future. The data used in this study is data on the purchase and sale of tire and oil products in the period March – August 2023.

FSN Analysis

In classifying using FSN analysis, there are several stages that are carried out, namely as follows [18]:

1. Determine the initial inventory obtained from the beginning of each observation period, the entry of goods obtained from product purchases, and product expenditure from product sales during the period March – August 2023.
2. Determine the final inventory for each tire and oil product. For GITI 750 R16 GAZ 891 KASAR products, the final setup is as follows:

$$Pakhir = Pawal + Pmasuk - Pkeluar \quad (1)$$
$$= 15 + 152 - 165$$
$$= 2 \text{ pcs}$$

3. Calculate the average inventory value for each tire and oil product in each observation period. The calculation for the GITI 750 R16 GAZ 891 KASAR product is as follows:

$$Prt = \frac{Pawal+Pakhir}{2} \quad (2)$$
$$= \frac{\frac{15+2}{2}}{2}$$
$$= 8{,}5 \text{ pcs}$$

4. Calculate the partial turn over ratio (TORp) value for each tire and oil product during the observation period. The TORp calculation for GITI 750 R16 GAZ 891 KASAR products is as follows:

$$TORp = \frac{Pkeluar}{Prt} \quad (3)$$
$$= \frac{165}{8{,}5}$$
$$= 19{,}41 \text{ times}$$

5. Calculate the storage time for each tire and oil product when the product is stored until the product is released. The number of days during the observation period is 184 days. The calculation of the average storage time during the observation period for GITI 750 R16 GAZ 891 GROSS products is as follows:

$$Wsp = \frac{Jhp}{TORp} \quad (4)$$
$$= \frac{184}{19{,}41}$$
$$= 9{,}48 \text{ days}$$

6. Calculate the value of the Turn over ratio (TOR) for each tire and oil product for one year. The number of days in a year is 365 days. The TOR values for GITI 750 R16 GAZ 891 KASAR products are as follows:

$$TOR = \frac{Jht}{Wsp} \quad (5)$$
$$= \frac{365}{9{,}48}$$
$$= 39 \text{ times}$$

7. Group products by value Turn over ratio (TOR) that has been obtained to determine the classification of each product. Product grouping with FSN analysis is assessed based on TOR value. Products are grouped as Fast moving when the TOR value > 3, grouped Slow moving when the TOR value is in the value range of $3 \leq TOR \leq 1$, and is grouped as Non moving when the TOR value < 1 [19].

Table 1. Classification of fsn analysis

Product Name	Initial Stock	Purchase	Sales	Ending Stock	Average Inventory	TORp	Wsp	TOR	Category
GITI 750 R16 GAR 890 HALUS	0	60	59	1	0.5	118.00	1.56	234	F
MEDITRAN SC 2X10L	5	245	250	0	2.5	100.00	1.84	198	F
BAN DALAM 750 R16 GT	5	600	598	7	6	99.67	1.85	198	F
MESRAN SUPER 20W50 20X1L	5	100	105	0	2.5	42.00	4.38	83	F
BAN DALAM 600/700 R14 GT	7	78	84	1	4	21.00	8.76	42	F

Product Name	Initial Stock	Purchase	Sales	Ending Stock	Average Inventory	TORp	Wsp	TOR	Category
GITI 750 R16 GAZ 891 KASAR	15	152	165	2	8.5	19.41	9.48	39	F
RORED HDA 140 4X5L	19	168	182	5	12	15.17	12.13	30	F
RORED HDA 90 6X4L	20	183	196	7	13.5	14.52	12.67	29	F
GT 640 R13 TRACTION PRO	5	80	79	6	5.5	14.36	12.81	28	F
GT 185/70 R14 CHAMPIRO ECOTEC	7	49	55	1	4	13.75	13.38	27	F
RORED EPA 140 4X5L	21	192	202	11	16	12.63	14.57	25	F
RORED EPA 90 6X4L	12	90	94	8	10	9.40	19.57	19	F
GT 700 R14 8PR SUPER	8	44	49	3	5.5	8.91	20.65	18	F
BS 265/65 R17 MT	2	6	8	0	1	8.00	23.00	16	F
BAN DALAM 1000 R20 GT	11	53	58	6	8.5	6.82	26.97	14	F
OLI 2T ORANGE	5	12	16	1	3	5.33	34.50	11	F
GT 185/65 R15 CHAMPIRO ECOTEC	3	10	11	2	2.5	4.40	41.82	9	F
ACCELERA 195/60 R15 ECO PLUSH	2	8	8	2	2	4.00	46.00	8	F
CASTROL GTX 15W-40 6X4L	7	7	14	0	3.5	4.00	46.00	8	F
ACCELERA 265/60 R18 MT	5	8	11	2	3.5	3.14	58.55	6	F
GT 195 R14 8PR MAXMILER PRO	13	20	26	7	10	2.60	70.77	5	F
GT 31X10.5 R15 SAVERO KOMODO EXTREME	9	10	13	6	7.5	1.73	106.1	3	S
GT 900 R20 MILER99	4	5	6	3	3.5	1.71	107.3	3	S
BS DURAVIS 195 R14	10	10	13	7	8.5	1.53	120.3	3	S
IDEMITSU SN 5W-30 24X1LTR BENSIN	5	3	4	4	4.5	0.89	207	2	S

Based on **Table 1**, it is known that there are 21 oil tire products that are included in the F (Fast) group, 4 oil tire products that are included in the S (Slow) group, and there are no products that are included in the Non-moving group. Products that are included in the Fast moving group are based on a TOR value above 3 (TOR>3). The results of this classification with FSN analysis show that the majority of oil tire products that experience stockouts have a high level of stock rotation. The higher the stock rotation rate, the higher the risk of stock shortages. So, useful follow-up actions are needed to optimize the inventory of these products. Therefore, a Monte Carlo simulation will be carried out to predict sales in the next 6 months to optimize inventory in terms of inventory procurement plans.

Monte Carlo Simulation

Monte Carlo simulations were carried out to obtain the results of future sales predictions. Sales prediction with Monte Carlo simulation is focused on 21 oil tire products that are categorized fast moving, with a prediction period span for the next 6 months, starting from September 2023 – February 2024. The steps in the Monte Carlo simulation are as follows [20]:

1. Determine the distribution of probability on each sale in each period. The equations used are as follows:

$$DP = \frac{P}{TP} \quad (6)$$

2. Determines the cumulative probability distribution by summing each value of the probability distribution by the value of the previous probability distribution. The first cumulative distribution value is the value of its probability distribution. The cumulative probability distribution is calculated using the following equation:

$$PK = \frac{P_n}{P_{n-1}} \quad (7)$$

3. Specifies the random number interval of the cumulative result of the distribution. The interval of a random number is set based on its cumulative probability value [21].
4. Generate a random number.
5. Create a simulation from a series of experiments and multiple replications.
6. Compare simulation results with actual data to obtain accuracy values.
7. Analyze the simulation results as an input in problem solving and policy formulation.

Table 2. Monte carlo simulation

Product Name	Months	Sales (pcs)	Probability	Cumulative Probability	Random Interval
GITI 750 R16 GAZ 891 KASAR	Maret	36	0.218	0.218	0 - 0,218
	April	21	0.127	0.345	0,219 – 0,345
	May	34	0.206	0.552	0,346 – 0,552
	June	23	0.139	0.691	0,553 – 0,691
	July	28	0.170	0.861	0,692 – 0,861
	August	23	0.139	1	0,862 - 1
	Total	165	1		

Table 3. Monte carlo simulation (continued)

Product Name	Iteration	Random Number (Simulation Results)					
		Sep 23	Oct 23	Nov 23	Dec 23	Jan 24	Feb 24
GITI 750 R16 GAZ 891 KASAR	1	0,627 (23)	0,417 (34)	0,533 (34)	0,183 (36)	0,969 (23)	0,791 (28)
	2	0,496 (34)	0,997 (23)	0,103 (36)	0,868 (23)	0,123 (36)	0,663 (23)
	3	0,422 (34)	0,574 (23)	0,893 (23)	0,913 (23)	0,846 (28)	0,258 (21)
	4	0,946 (23)	0,871 (23)	0,794 (28)	0,841 (28)	0,315 (21)	0,651 (23)
	5	0,888 (23)	0,597 (23)	0,297 (21)	0,525 (34)	0,761 (28)	0,729 (28)
	6	0,195 (36)	0,627 (23)	0,465 (34)	0,728 (28)	0,707 (28)	0,732 (28)
	7	0,819 (28)	0,508 (34)	0,231 (21)	0,430 (34)	0,197 (36)	0,902 (23)
	8	0,300 (21)	0,589 (23)	0,016 (36)	0,200 (36)	0,419 (34)	0,488 (34)
	9	0,502 (34)	0,719 (28)	0,143 (36)	0,053 (36)	0,263 (21)	0,843 (28)
	10	0,773 (28)	0,223 (21)	0,960 (23)	0,156 (36)	0,363 (34)	0,118 (36)
Average		28,4	25,5	29,2	31,4	28,9	27,2

Table 4. Monte Carlo simulation prediction results

Product Name	Simulation Results (pcs)					
	September 23	October 23	November 23	December 23	January 24	February 24
GITI 750 R16 GAR 890 HALUS	9	13	11	13	11	10
MEDITRAN SC 2X10L	47	50	40	46	41	48
BAN DALAM 750 R16 GT	87	91	118	112	109	101
MESRAN SUPER 20W50 20X1L	25	15	16	18	24	22
BAN DALAM 600/700 R14 GT	14	16	17	15	12	15
GITI 750 R16 GAZ 891 KASAR	28	26	29	31	29	27
RORED HDA 140 4X5L	28	35	32	35	31	34
RORED HDA 90 6X4L	38	30	34	32	33	36
GT 640 R13 TRACTION PRO	12	15	17	17	18	13

GT 185/70 R14 CHAMPIRO ECOTEC	10	9	9	11	9	11
RORED EPA 140 4X5L	36	42	40	30	36	38
RORED EPA 90 6X4L	17	14	18	15	15	16
GT 700 R14 8PR SUPER	9	9	7	8	8	8
BS 265/65 R17 MT	2	1	2	1	1	2
BAN DALAM 1000 R20 GT	11	11	9	12	8	12
OLI 2T ORANGE	3	2	3	2	3	4
GT 185/65 R15 CHAMPIRO ECOTEC	2	2	2	3	2	2
ACCELERA 195/60 R15 ECO PLUSH	1	1	1	1	1	1
CASTROL GTX 15W-40 6X4L	3	3	3	3	3	3
ACCELERA 265/60 R18 MT	2	1	2	2	3	2
GT 195 R14 8PR MAXMILER PRO	7	5	4	5	5	7

Table 2 above is a calculation of probability, cumulative probability, and random intervals. The value of cumulative probability describes how often sales will reach a certain number of sales for a product. Random number interval determination is used to generate a random number that is determined from the distribution of the probability of selling tire and oil products. Random intervals are used as the minimum and maximum limits in generating random numbers. The minimum value starts at 0 and the maximum value is its cumulative value. The minimum value for the next variable is obtained from the previous maximum limit and added to the value of 0.001. After determining the random interval, the stages of generating random numbers are carried out as shown in **Table 3**. Generate random numbers using the excel function =RAND(). Random number generation is carried out 10 iterations on each product. **Table 3** above also shows the results of the simulation, where the number value included in the random number interval is the value of the simulation results that will be used as a prediction of tire and oil sales. For example, in September 2023 for the 1st iteration, the random number obtained is 0.627 where the value is in the interval of 0.553-0.691 based on Table 4.6 with a sales volume of 23 and so on. After 10 repetitions, the simulation prediction results were averaged to get the final prediction value. Thus, the results of the GITI 750 R16 GAZ 891 KASAR product sales prediction for September 2023 are 28.4 or 28 pcs. **Table 4** is a recapitulation of sales prediction results using Monte Carlo simulations for 21 tire and oil products that are categorized as fast moving.

After obtaining the sales prediction results with the monte carlo simulation, it will then be compared with the actual data by conducting the MAD, MSE, and MAPE accuracy tests, so that the accuracy value is obtained to assess how well the simulation model can represent the data used to develop the model [22]. Accuracy test calculation for the product GITI 750 R16 GAZ 891 KASAR are as follows [23]:

$$MAD = \frac{1}{n}\sum_{t=1}^{n}|At - Ft| \quad (8)$$
$$= \frac{1}{6}(|23-28| + |23-26| + |28-29| + |30-31| + |28-29| + |24-27|)$$
$$= \frac{1}{6}(5+3+1+1+1+3)$$
$$= \frac{1}{6}(14) = 2{,}33$$

$$MSE = \frac{1}{n}\sum_{t=1}^{n}(At - Ft)^2 \quad (9)$$
$$= \frac{1}{6}(23-28)^2 + (23-26)^2 + (28-29)^2 + (30-31)^2 + (28-29)^2 + (24-27)^2$$
$$= \frac{1}{6}(25+9+1+1+1+9)$$
$$= \frac{1}{6}(46) = 7{,}67$$

$$MAPE = \frac{100}{n}\sum_{t=1}^{n}\frac{|At-Ft|}{At} \quad (10)$$
$$= \frac{100}{6}(\frac{|23-28|}{23} + \frac{|23-26|}{23} + \frac{|28-29|}{28} + \frac{|30-31|}{30} + \frac{|28-29|}{28} + \frac{|24-27|}{24}$$
$$= \frac{100}{6}(0{,}217 + 0{,}13 + 0{,}035 + 0{,}033 + 0{,}035 + 0{,}125$$
$$= \frac{100}{6}(0{,}575) = 9{,}6\%$$

Table 5. GITI 750 R16 GAZ 891 KASAR product accuracy test

Months	Simulation Results	Actual Data	MAD	MSE	MAPE (%)
September 2023	28	23	2,33	7,67	9,6
October 2023	26	23			
November 2023	29	28			
December 2023	31	30			
January 2024	29	28			
February 2024	27	24			
Total	**170**	**156**			

Based on the simulation results on the GITI 750 R16 GAZ 891 ROUGH product from September 2023 - February 2024, sales of 170 pcs were obtained. The MAD value is around 2.33 pcs which indicates that the prediction has a relatively small error rate overall. The MSE value is around 7.67 pcs which shows that there is a small variation because there are several significant prediction results with actual results. The MAPE value of 9.6% indicates that the accuracy of the prediction results with the monte carlo simulation is said to be very good.

Safety Stock

To optimize the supply of oil tires, it will be used service level by 95% (z = 1.65), where lead time delivery of the product is 5 days. Before the calculation safety stock, the standard deviation will first be calculated using the excel =STDEV. P, so that the standard deviation value for the product is obtained GITI 750 R16 GAZ 891 KASAR is 5.74. The equation used to calculate safety stock are as follows [24]:

$$Safety\ Stock = Z\ \sigma\ \sqrt{LT} \quad (11)$$
$$= 1{,}65 \text{ x } 5{,}74 \text{ x } \sqrt{5}$$
$$= 21{,}17 \approx 21 \text{ pcs} \approx 3 - 4 \text{ pcs/month}$$

Based on the results of the calculation, it was obtained that the amount of safety supplies that must be provided for GITI 750 R16 GAZ 891 KASAR products is as many as 21 pcs or around 3-4 pcs/month.

Reorder Point

Determination reorder point is carried out to determine the point when to reorder products to prevent stock shortages by using leadtime = 5 days ≈ 0.17 months. The equation used to calculate reorder point are as follows [25]:

$$Reorder\ Point = (d\ x\ LT) + Safety\ Stock \quad (12)$$
$$= \left(\frac{170}{6} \text{ x } 0{,}17\right) + \frac{21}{6}$$
$$= 8{,}31 \approx 8 \text{ pcs}$$

Based on the calculation results, it was obtained that the return order point was 8 pcs. Where, if the inventory of GITI 750 R16 GAZ 891 KASAR products has reached 8 pcs, then it is necessary to reorder the product.

Conclusion

Based on product classification with FSN analysis, it was found that 21 out of 25 products or about 84% of oil tire products were classified as fast moving. From the results of the classification, the products with the highest TOR value were GITI 750 R16 GAR 890 HALUS with a turn over ratio of 234, MEDITRAN SC 2X10L with a turn over ratio of 198, INNER TIRE 750 R16 GT with a Turn over ratio of 198, MESRAN SUPER 20W50 20X1L with a Turn over ratio of 83, and INNER TIRE 600/700 R14 GT with a Turn over ratio 42. Therefore, these 21 products must be given special attention and used as inputs in the processing of Monte Carlo simulations. The prediction of tire and oil sales using Monte Carlo simulation shows that the sales prediction results are quite accurate, as evidenced by the calculation of an accuracy test that results in an MAD value of 2.33, MSE of 7.67, and MAPE of 9.6%. Based on processing with Monte Carlo simulations, when compared to actual data, there are the number of products that exceed and are less than the amount of actual data., for example the GITI 750 R16 GAZ 891 COARSE product, where the prediction data with Monte Carlo simulations from September 2023 - February 2024 is 28, 26, 29, 31, 29, and 27 pcs which are compared to the actual data of 23, 23, 28, 30, 28, and 24 pcs. The results of the calculation of

safety stock and reorder point show that the optimal value of safety supplies for GITI 750 R16 GAZ 891 KASAR products is 3-4 pcs every month with the reorder point when the product stock has reached 8 pcs.

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